MCP1633
Automotive Tail Light Reference Design
Note the following details of the code protection feature on Microchip devices:

- Microchip products meet the specification contained in their particular Microchip Data Sheet.
- Microchip believes that its family of products is one of the most secure families of its kind on the market today, when used in the intended manner and under normal conditions.
- There are dishonest and possibly illegal methods used to breach the code protection feature. All of these methods, to our knowledge, require using the Microchip products in a manner outside the operating specifications contained in Microchip’s Data Sheets. Most likely, the person doing so is engaged in theft of intellectual property.
- Microchip is willing to work with the customer who is concerned about the integrity of their code.
- Neither Microchip nor any other semiconductor manufacturer can guarantee the security of their code. Code protection does not mean that we are guaranteeing the product as “unbreakable.”

Code protection is constantly evolving. We at Microchip are committed to continuously improving the code protection features of our products. Attempts to break Microchip’s code protection feature may be a violation of the Digital Millennium Copyright Act. If such acts allow unauthorized access to your software or other copyrighted work, you may have a right to sue for relief under that Act.

Information contained in this publication regarding device applications and the like is provided only for your convenience and may be superseded by updates. It is your responsibility to ensure that your application meets with your specifications. MICROCHIP MAKES NO REPRESENTATIONS OR WARRANTIES OF ANY KIND WHETHER EXPRESS OR IMPLIED, WRITTEN OR ORAL, STATUTORY OR OTHERWISE, RELATED TO THE INFORMATION, INCLUDING BUT NOT LIMITED TO ITS CONDITION, QUALITY, PERFORMANCE, MERCHANTABILITY OR FITNESS FOR PURPOSE. Microchip disclaims all liability arising from this information and its use. Use of Microchip devices in life support and/or safety applications is entirely at the buyer’s risk, and the buyer agrees to defend, indemnify and hold harmless Microchip from any and all damages, claims, suits, or expenses resulting from such use. No licenses are conveyed, implicitly or otherwise, under any Microchip intellectual property rights unless otherwise stated.

Trademarks
The Microchip name and logo, the Microchip logo, Adaptec, AnyRate, AVR, AVR logo, AVR Freaks, BesTime, BitCloud, chipKIT, chipKIT logo, CryptoMemory, CryptoRF, dsPIC, FlashFlex, flexPWR, HELDO, IGLOO, JukeBlox, KeeLog, Kleer, LANCheck, LinkMD, maXSylus, maXTouch, MediaLB, megaAVR, Microsemi, Microsemi logo, MOST, MOST logo, MPLAB, OptoLyzr, PackeTime, Pic, picPower, PICSTART, PIC32 logo, PolarFire, Prochip Designer, QTouch, SAM-BA, SenGenuity, SpyNIC, SST, SST Logo, SuperFlash, Symmetricom, SyncServer, Tachyon, TempTrackr, TimeSource, tinyAVR, UNI/O, Vectron, and XMEGA are registered trademarks of Microchip Technology Incorporated in the U.S.A. and other countries.

APT, ClockWorks, The Embedded Control Solutions Company, EtherSynch, FlashTec, Hyper Speed Control, HyperLight Load, IntelliMOS, Libero, motorBench, mTouch, Powermite 3, Precision Edge, ProASIC, ProASIC Plus, ProASIC Plus logo, Quiet-Wire, SmartFusion, SyncWorld, Temux, TimeCesium, TimeHub, TimePictra, TimeProvider, Vite, WinPath, and ZL are registered trademarks of Microchip Technology Incorporated in the U.S.A. and other countries.


SQTP is a service mark of Microchip Technology Incorporated in the U.S.A.

The Adaptec logo, Frequency on Demand, Silicon Storage Technology, and Symmcom are registered trademarks of Microchip Technology Inc. in other countries.

GestIC is a registered trademark of Microchip Technology Germany II GmbH & Co. KG, a subsidiary of Microchip Technology Inc., in other countries.

All other trademarks mentioned herein are property of their respective companies.

© 2020, Microchip Technology Incorporated, All Rights Reserved.

For information regarding Microchip’s Quality Management Systems, please visit www.microchip.com/quality.

ISBN: 978-1-5224-5329-1
## Preface ....................................................................................................................... 5

### Chapter 1. Product Overview

1.1 Introduction ..................................................................................................... 9
1.2 MCP1633 Automotive Tail Light Reference Design Overview ...................... 9
1.3 MCP1633 Automotive Tail Light Reference Design Features ..................... 10
1.4 Device Summary ....................................................................................... 10
1.5 Technical Specifications ........................................................................ 11
1.6 Functional Description ........................................................................... 12
1.7 What the MCP1633 Automotive Tail Light Reference Design Kit Contains ............................................................ 13

### Chapter 2. Installation and Operation

2.1 Getting Started ............................................................................................. 15
  2.1.1 Necessary Instruments and Tools ............................................................. 15
  2.1.2 Setup Procedure ..................................................................................... 15
  2.1.3 Board Testing ......................................................................................... 16
2.2 Evaluating the Application ............................................................................ 17
2.3 Firmware Description ................................................................................... 17

### Chapter 3. Connectivity via Bluetooth

3.1 Introduction ................................................................................................... 19
3.2 Installing the Android Application ................................................................. 19
3.3 Application Interface ..................................................................................... 19
  3.3.1 Starting the Application ............................................................................. 19
  3.3.2 Connecting to a Bluetooth Device ............................................................. 20
  3.3.3 Using the MCP1633 Automotive Tail Light Reference Design Android Application ................................................................................ 21

### Appendix A. Schematics and Layouts

A.1 Introduction .................................................................................................. 23
A.2 Schematic – REVERSE Block ..................................................................... 24
A.3 Schematic – FOG Block ............................................................................... 25
A.4 Schematic – TURN Block ............................................................................ 26
A.5 Schematic – BRAKE/POS Block .................................................................. 27
A.6 Schematic – MCU ........................................................................................ 28
A.7 Schematic – Bluetooth Connectivity ............................................................ 29
A.8 Board – Top Silk .......................................................................................... 29
A.9 Board – Top Copper .................................................................................... 30
A.10 Board – Top Copper and Silk ................................................................. 30
Appendix C. Typical Performance Data, Curves and Waveforms

C.1 Introduction ................................................................. 37
C.2 Brake IOUT Dimming ..................................................... 37
C.3 Brake IOUT Ripple .......................................................... 37
C.4 Fog - Minimum Level of Dimming ......................... 38
C.5 Fog IOUT Ripple ............................................................. 38
C.6 Position IOUT Ripple .................................................... 39
C.7 Turn IOUT Ripple ............................................................ 39
C.8 Turn VOUT and IOUT .................................................. 40
C.9 Turn All Steps Period of Time .............................. 40

Worldwide Sales and Service ............................................. 41
Preface

NOTICE TO CUSTOMERS

All documentation becomes dated, and this manual is no exception. Microchip tools and documentation are constantly evolving to meet customer needs, so some actual dialogs and/or tool descriptions may differ from those in this document. Please refer to our website (www.microchip.com) to obtain the latest documentation available.

Documents are identified with a “DS” number. This number is located on the bottom of each page, in front of the page number. The numbering convention for the DS number is “DSXXXXXXXXA”, where “XXXXXXXX” is the document number and “A” is the revision level of the document.

For the most up-to-date information on development tools, see the MPLAB® IDE online help. Select the Help menu, and then Topics, to open a list of available online help files.

INTRODUCTION

This chapter contains general information that will be useful to know before using the MCP1633 Automotive Tail Light Reference Design. Items discussed in this chapter include:

• Document Layout
• Conventions Used in this Guide
• Recommended Reading
• The Microchip Website
• Customer Support
• Document Revision History

DOCUMENT LAYOUT

This document describes how to use the MCP1633 Automotive Tail Light Reference Design as a development tool to emulate and debug firmware on a target board. The manual layout is as follows:

• Chapter 1. “Product Overview” – Important information about the MCP1633 Automotive Tail Light Reference Design.
• Chapter 2. “Installation and Operation” – Includes instructions on installing and operating the MCP1633 Automotive Tail Light Reference Design.
• Chapter 3. “Connectivity via Bluetooth” – Contains instructions on how to connect to the MCP1633 Automotive Tail Light Reference Design via Bluetooth and how to use the Android application.
• Appendix A. “Schematics and Layouts” – Shows the schematic and layout diagrams for the MCP1633 Automotive Tail Light Reference Design.
• Appendix B. “Bill of Materials (BOM)” – Lists the parts used to build the MCP1633 Automotive Tail Light Reference Design.
• Appendix C. “Typical Performance Data, Curves and Waveforms” - Contains typical performance curves and waveforms for the MCP1633 Automotive Tail Light Reference Design.
### CONVENTIONS USED IN THIS GUIDE

This manual uses the following documentation conventions:

#### DOCUMENTATION CONVENTIONS

<table>
<thead>
<tr>
<th>Description</th>
<th>Represents</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Arial font:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Italic characters</td>
<td>Referenced books</td>
<td><em>MPLAB® IDE User’s Guide</em></td>
</tr>
<tr>
<td>Emphasized text</td>
<td></td>
<td>...is the only compiler...</td>
</tr>
<tr>
<td>Initial caps</td>
<td>A window</td>
<td>the Output window</td>
</tr>
<tr>
<td></td>
<td>A dialog</td>
<td>the Settings dialog</td>
</tr>
<tr>
<td></td>
<td>A menu selection</td>
<td>select Enable Programmer</td>
</tr>
<tr>
<td>Quotes</td>
<td>A field name in a window or dialog</td>
<td>“Save project before build”</td>
</tr>
<tr>
<td>Underlined, italic text with right angle bracket</td>
<td>A menu path</td>
<td><em>File&gt;Save</em></td>
</tr>
<tr>
<td>Bold characters</td>
<td>A dialog button</td>
<td>Click OK</td>
</tr>
<tr>
<td></td>
<td>A tab</td>
<td>Click the <em>Power</em> tab</td>
</tr>
<tr>
<td>N'RNnnnn</td>
<td>A number in verilog format, where N is the total number of digits, R is the radix and n is a digit.</td>
<td>4'b0010, 2'hF1</td>
</tr>
<tr>
<td>Text in angle brackets &lt; &gt;</td>
<td>A key on the keyboard</td>
<td>Press &lt;Enter&gt;, &lt;F1&gt;</td>
</tr>
<tr>
<td><strong>Courier New font:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plain Courier New</td>
<td>Sample source code</td>
<td>#define START</td>
</tr>
<tr>
<td></td>
<td>Filenames</td>
<td><em>autoexec.bat</em></td>
</tr>
<tr>
<td></td>
<td>File paths</td>
<td>c:\mcc18\h</td>
</tr>
<tr>
<td></td>
<td>Keywords</td>
<td>_asm, _endasm, static</td>
</tr>
<tr>
<td></td>
<td>Command-line options</td>
<td>-Opa+, -Opa-</td>
</tr>
<tr>
<td></td>
<td>Bit values</td>
<td>0, 1</td>
</tr>
<tr>
<td></td>
<td>Constants</td>
<td>0xFF, ‘A’</td>
</tr>
<tr>
<td>Italic Courier New</td>
<td>A variable argument</td>
<td>file.o, where file can be any valid filename</td>
</tr>
<tr>
<td>Square brackets [ ]</td>
<td>Optional arguments</td>
<td>mcc18 [options] file [options]</td>
</tr>
<tr>
<td>Curly brackets and pipe character: { }</td>
<td>Choice of mutually exclusive arguments; an OR selection</td>
<td>errorlevel {0</td>
</tr>
<tr>
<td>Ellipses...</td>
<td>Replaces repeated text</td>
<td>var_name [], var_name...</td>
</tr>
<tr>
<td></td>
<td>Represents code supplied by user</td>
<td>void main (void) { ... }</td>
</tr>
</tbody>
</table>
RECOMMENDED READING

This user’s guide describes how to use the MCP1633 Automotive Tail Light Reference Design. Another useful document is listed below. The following Microchip document is available and recommended as a supplemental reference resource:

- MCP1633 Data Sheet – “Low-Side PWM Controller with LED Dimming Capability” (DS20006289)

THE MICROCHIP WEBSITE

Microchip provides online support via our website at www.microchip.com. This website is used as a means to make files and information easily available to customers. Accessible by using your favorite Internet browser, the website contains the following information:

- **Product Support** – Data sheets and errata, application notes and sample programs, design resources, user’s guides and hardware support documents, latest software releases and archived software
- **General Technical Support** – Frequently Asked Questions (FAQs), technical support requests, online discussion groups, Microchip consultant program member listing
- **Business of Microchip** – Product selector and ordering guides, latest Microchip press releases, listing of seminars and events, listings of Microchip sales offices, distributors and factory representatives

CUSTOMER SUPPORT

Users of Microchip products can receive assistance through several channels:

- Distributor or Representative
- Local Sales Office
- Field Application Engineer (FAE)
- Technical Support

Customers should contact their distributor, representative or field application engineer (FAE) for support. Local sales offices are also available to help customers. A listing of sales offices and locations is included in the back of this document.

Technical support is available through the website at: http://www.microchip.com/support.

DOCUMENT REVISION HISTORY

**Revision A (April 2020)**

- Initial release of this document.
Chapter 1. Product Overview

1.1 INTRODUCTION

This chapter provides an overview of the MCP1633 Automotive Tail Light Reference Design and covers the following topics:

• MCP1633 Automotive Tail Light Reference Design Overview
• MCP1633 Automotive Tail Light Reference Design Features
• A summary of the primary devices used on the MCP1633 Automotive Tail Light Reference Design board
• MCP1633 Automotive Tail Light Reference Design technical specifications and functional description
• What the MCP1633 Automotive Tail Light Reference Design Kit contains.

1.2 MCP1633 AUTOMOTIVE TAIL LIGHT REFERENCE DESIGN OVERVIEW

The MCP1633 Automotive Tail Light Reference Design uses a step-up/step-down, switch-mode, DC/DC converter for LED driver applications. The board demonstrates several applications that simulate a tail light. It can be controlled either directly in stand-alone mode or from a phone, tablet or other mobile device by using an Android application. MCP1633 Automotive Tail Light Reference Design features Microchip’s MCP1633 high-speed Pulse-Width Modulator (PWM). The MCP1633 comes in a small 16-pin QFN package and contains all the analog components necessary for a peak current mode control loop including specialized LED driver blocks. A 28-pin PIC16F15355 microcontroller is used to implement all the functions on the board.

FIGURE 1-1: MCP1633 Automotive Tail Light Reference Design - Top View.
1.3 MCP1633 AUTOMOTIVE TAIL LIGHT REFERENCE DESIGN FEATURES

- The MCP1633 Automotive Tail Light Reference Design has the following features:
  - Can operate in Buck (step-down) or Boost (step-up) mode
  - Factory-programmed source code provider
  - Additional application functions can be implemented in the firmware
  - Typical current of 200 mA; can be adjusted via hardware
  - Sustain voltage stresses typically found in automotive products: 42V input for 180 ms
  - High output power

1.4 DEVICE SUMMARY

The MCP1633 Automotive Tail Light Reference Design uses the following primary devices on the board:

- Four MCP1633 High-Speed PWM Controllers
  - When used in conjunction with the microcontroller, the MCP1633 devices will control the power system duty cycle to provide output current and/or voltage regulation.
- PIC16F15355 microcontroller (8-bit MCU)
  - Used to implement the dimming function, manage faults and protect the on-board load from overheating.
- MCP1790 Low-Dropout Regulator (LDO)
  - Used to supply regulated voltage (+5V) to the PIC16F15355 microcontroller, the four MCP1633 PWM Controllers and the four MCP9700 Temperature Sensors.
- Four MCP9700 Low-Power Voltage Output Temperature Sensor
  - Used to measure the temperature of the LED strings.
- MCP1703 Low-Dropout Regulator (LDO)
  - Used to supply regulated voltage (+3.3V) to the RN4871 Bluetooth Module.
- RN4871 Low-Energy Bluetooth Module
1.5 TECHNICAL SPECIFICATIONS

- Input voltage: +8V to +16V (surge voltage of 42V for max. 180 ms, 30 seconds repetition rate
- Configurable undervoltage lock-out circuit software (8V and 16V default thresholds)
- Overvoltage protection, hardware configurable for each block. The overvoltage threshold values are:
  - 27V for the BRAKE/POS block
  - 27V for the TURN block
  - 16V for the FOG block
  - 16V for the REVERSE block
- Typical output current set at 200 mA for all blocks (with hardware adjustments)
- Fully protected against Short-Circuit and No-Load conditions

Figure 1-2 shows a simplified block diagram of the application.
1.6 FUNCTIONAL DESCRIPTION

The MCP1633 Low-Side PWM Controller provides all the analog functions necessary to implement a stand-alone LED driver. When combined with an external microcontroller, the MCP1633 can be used to implement various smart converters, such as those necessary for LED drivers.

The MCP1633 Automotive Tail Light Reference Design board uses four MCP1633, configured independently in each of the four blocks that describe the different functions served by an automotive tail light: "BRAKE/POS", "FOG", "REVERSE" and "TURN". The power trains use the Single-Ended Primary Inductor Converter (SEPIC) topology. The converters provide constant currents with limited voltage at the output, necessary for LED driver applications. The average current in the L1B inductor, which is also the output current of the converter, is sensed using a 0.1\( \Omega \) shunt resistor (RS). As the voltage across the shunt resistor is negative, the internal amplifier is set to -10x gain and the output is connected to the FB pin.

The conversion gain of this circuit is 1V/A.

The output current is set by \( R_{VREF} \).

Output current can be calculated with equation 1:

\[
I_{OUT} = \frac{V_{REF}}{R_2 \times R_S}
\]

The resulting values for the application are:

\[
V_{REF} = I_{OUT} \times R_S \times \frac{R_2}{R_1} = 200 \text{ mV}
\]

\[
R_{VREF} = \frac{V_{REF}}{50 \mu A} = 4 \text{ k}\Omega
\]

The BRAKE/POS, FOG and REVERSE blocks use simple LED string and function in continuous mode.

The TURN block has a variable LED string and uses MOSFETs to control the turn-on and turn-off sequences from the PWM signal generated by the microcontroller. The TURN block also has an NMOS used for discharging from high voltage to low voltage when the light cycle starts and stops. This ensures that the LEDs are protected. The period for the dynamic light is 860 ms and the period for each step is 40 ms (see Figure 1-3). The resulting 1.16 Hz frequency is optimal for automotive specifications.

\[
\text{FIGURE 1-3: } V_{OUT \text{ TURN Block Time Voltage}}
\]
1.7 WHAT THE MCP1633 AUTOMOTIVE TAIL LIGHT REFERENCE DESIGN KIT CONTAINS

The MCP1633 Automotive Tail Light Reference Design includes the following items:

- MCP1633 Automotive Tail Light Reference Design Board (ARD01038)
- Important Information Sheet
- Link to installing the Android application to connect from a phone or tablet.
Chapter 2. Installation and Operation

2.1 GETTING STARTED

The MCP1633 Automotive Tail Light Reference Design is fully assembled and tested. The board requires an external input voltage source (+8V to +16V).

2.1.1 Necessary Instruments and Tools

The following instruments and tools are necessary to install and operate the MCP1633 Automotive Tail Light Reference Design:

- Adjustable DC power supply with 0V-24V/3 ADC range output capability
- Digital oscilloscope with a minimum bandwidth of 50 MHz
- Signal generator
- Digital voltmeter/ammeter
- Wires for connections

2.1.2 Setup Procedure

Follow these steps prior to using the MCP1633 Automotive Tail Light Reference Design:

1. Connect a power supply to the input connector J, the “Positive” (+) and “Negative” (-) connector pins are marked on the board’s silk screen.
2. Connect the jumper on the Load Connectors to connect the LED's.
3. The DC voltage supplied by the Adjustable DC Power Supply must be between 6V and 16V.
4. Turn on the power supply.
2.1.3 Board Testing

The typical testing setup is depicted in Figure 2-1.
2.2 EVALUATING THE APPLICATION

The best way to evaluate the MCP1633 SEPIC LED Driver is to examine the circuit and measure voltages and currents with a digital voltage meter and probe the board with an oscilloscope.

Additional tools are necessary to evaluate some technical parameters of the board (temperature of power components, ability to withstand surge voltage pulse on input, EMI).

The firmware program in the PIC16F15355 can also be edited to modify the operation of the application.

2.3 FIRMWARE DESCRIPTION

The program starts with the initialization routine. Pins RC0, RC1 and RC2 are configured to output the PWM dimming for three of the four MCP1633 devices. Pin RC3 is set as the output pin for the fourth MCP1633. The LED intensity is adjusted by changing the duty cycle of the PWM. The frequency is 244 Hz (4.096 ms). The SYNC/EN clock signal is generated by pin RC5 with a frequency of 500 kHz.

The Capture/Compare/PWM (CCP) is configured for PWM mode operation and used for PWM dimming the LEDs. The PWM period can be calculated by writing to the PR2 register of the PIC16F15355. The PWM duty cycle is specified by writing to the CCPR1L register and to the CCP1CON[5:4] bits. Up to 10-bit resolution is available. The CCPR1L register contains the eight MSbs. The CCP1CON[5:4] bits contain the two LSbs. This 10-bit value is represented by CCPR1L:CCP1CON[5:4].

The analog inputs are used to measure the input voltage and the temperature of each of the LED strings. If the voltage is lower than 9V or higher than 16V the microcontroller will enter a voltage protection routine. If the temperature on one string is higher than +90°C the PWM for that string will be disabled and the DIMM pin will be set to zero and it will remain there until the temperature drops to +70°C.

The “No-Load condition” protection is provided by the FAULT pin of the MCP1633 and handled by the microcontroller. If the output voltage is too high and the overvoltage threshold is reached, the FAULT pin goes low and an interrupt occurs. The PWM is disabled and the DIMM pin is set “zero”. A timer starts and if no Fault conditions exists for a period of 1 s, the converter will resume normal operation.

For the turning light on the dimming pin no PWM is used. Four I/O pins control the LED segments using a timer to increment the number of segments lit. When the last segment is lit a MOSFET is used to discharge the output capacitor.
FIGURE 2-2: MCP1633 LED Driver Block Diagram.
Chapter 3. Connectivity via Bluetooth

3.1 INTRODUCTION

This chapter contains information on how to take advantage of the Bluetooth connectivity capabilities of the MCP1633 Automotive Tail Light Reference Design and on the accompanying Android application.

3.2 INSTALLING THE ANDROID APPLICATION

The application can be found on the product page and is designed exclusively for the Android OS.

3.3 APPLICATION INTERFACE

3.3.1 Starting the Application

Figure 3-1 shows the Application’s interface at start-up. Notice the menu icon highlighted in red in the top-left corner of the interface.

![Android Application – First Look](image-url)
3.3.2 Connecting to a Bluetooth Device

Access the menu for Bluetooth devices (see Figure 3-2). Tap the Refresh button at the bottom of the menu and then wait for the list of Bluetooth devices to populate. Tap on the list item that corresponds to the desired device and then wait for the Bluetooth device to sync with the board. The application will display a text message that says “Connection is successful” after the connection has been established, as shown in Figure 3-3.

![Figure 3-2: Android Application – Connect to Board Bluetooth Module.](image)

![Figure 3-3: Android Application – Connection is Successful.](image)
3.3.3 Using the MCP1633 Automotive Tail Light Reference Design

Android Application

Figure 3-4 shows the application's control interface for the MCP1633 Automotive Tail Light Reference Design.

![Android Application – Control Interface.](image)

The control interface, depicted in Figure 3-4, features eight buttons that can be tapped to access the various functionalities provided by the MCP1633 Automotive Tail Light Reference Design:

1. Two buttons for the TURN function. Tap these buttons to activate the turning lights sequence on the board.
2. POSITION function – tap here to activate the position lights.
3. The FOG function button activates the board’s fog lights functionality.
4. REVERSE function: press this button to activate the REVERSE lights.
5. The BRAKE function can be activated via two buttons: one customized as a brake pedal in the bottom-left side of the interface and one ‘BRAKE’ button placed towards the middle-right side.
6. A START/STOP button. Must be pressed first to start the application.
7. The FOG block can be activated by the “PWM Fog Lights” slider. Move the slider to change the intensity of the fog lights.
NOTES:
Appendix A. Schematics and Layouts

A.1 INTRODUCTION

This Appendix contains the following schematics and layouts for the MCP1633 Automotive Tail Light Reference Design - ARD01038:

• Schematic – REVERSE Block
• Schematic – FOG Block
• Schematic – TURN Block
• Schematic – BRAKE/POS Block
• Schematic – MCU
• Schematic – Bluetooth Connectivity
• Board – Top Silk
• Board – Top Copper
• Board – Top Copper and Silk
• Board – Bottom Copper
• Board - Bottom Silk
• Board - Bottom Copper and Silk
A.7 SCHEMATIC – BLUETOOTH CONNECTIVITY

RN4871 BLUETOOTH MODULE AND CONFIGURATION CIRCUITS

Bluetooth Module Reset Circuit

MCP2221 CONNECTOR

3V3 LDO FROM DN2470

A.8 BOARD – TOP SILK
## Appendix B. Bill of Materials (BOM)

### TABLE B-1: BILL OF MATERIALS (BOM)

<table>
<thead>
<tr>
<th>Qty</th>
<th>Reference</th>
<th>Description</th>
<th>Manufacturer</th>
<th>Manufacturer Part Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>C1</td>
<td>Capacitor, ceramic, 0.1 µF, 50V, 10%, X7R, surface mount, 0805</td>
<td>KEMET</td>
<td>C0805C104K5RACTU</td>
</tr>
<tr>
<td>2</td>
<td>C2, C75</td>
<td>Capacitor, ceramic, 1 µF, 25V, 10%, X7R, surface mount, 0805</td>
<td>AVX Corporation</td>
<td>08053C105K4Z2A</td>
</tr>
<tr>
<td>1</td>
<td>C3</td>
<td>Capacitor, ceramic, 1 µF, 50V, 20%, Y5V, surface mount, 0805</td>
<td>Samsung Electro-Mechanics America, Inc.</td>
<td>CL21F105ZBFNNNE</td>
</tr>
<tr>
<td>18</td>
<td>C5, C6, C8, C9, C10, C12, C27, C28, C30, C43, C44, C46, C47, C48, C50, C61, C62, C63, C64</td>
<td>Capacitor, ceramic, 10 µF, 50V, 20%, X7S, surface mount, 1210</td>
<td>TDK Corporation</td>
<td>C3225X7S1H106M250AB</td>
</tr>
<tr>
<td>4</td>
<td>C7, C29, C45, C58</td>
<td>Capacitor, ceramic, 4.7 µF, 25V, 10%, X7R, surface mount, 0805</td>
<td>TDK Corporation</td>
<td>C2012X7R1E475K125AB</td>
</tr>
<tr>
<td>1</td>
<td>C11</td>
<td>Capacitor, ceramic, 10 µF, 10V, 10%, X5R, surface mount, 0805</td>
<td>Taiyo Yuden Co., Ltd.</td>
<td>LMK212BJ106KG-T</td>
</tr>
<tr>
<td>9</td>
<td>C12, C13, C19, C21, C40, C54, C56, C70, C72</td>
<td>Capacitor, ceramic, 0.1 µF, 16V, 10%, X7R, surface mount, 0603</td>
<td>Taiyo Yuden Co., Ltd.</td>
<td>EMK107B7104KA-T</td>
</tr>
<tr>
<td>16</td>
<td>C14, C15, C17, C20, C33, C34, C36, C39, C49, C50, C52, C55, C65, C66, C68, C71</td>
<td>Capacitor, ceramic, 10000 pF, 50V, 20%, X7R, surface mount, 0603</td>
<td>AVX Corporation</td>
<td>06035C103KAT2A</td>
</tr>
<tr>
<td>4</td>
<td>C16, C35, C51, C67</td>
<td>Capacitor, ceramic, 33 pF, 50V, 5%, C0G, surface mount, 0603</td>
<td>Murata Electronics North America, Inc.</td>
<td>GRM1885C1H330JA01D</td>
</tr>
<tr>
<td>4</td>
<td>C18, C37, C53, C69</td>
<td>Capacitor, ceramic, 47 pF, 50V, 5%, NP0, surface mount, 0603</td>
<td>KEMET</td>
<td>C0603C470J5GACTU</td>
</tr>
<tr>
<td>4</td>
<td>C22, C41, C57, C73</td>
<td>Capacitor, ceramic, 100 pF, 50V, 5%, NP0, surface mount, 0603</td>
<td>Cal-Chip Electronics Inc.</td>
<td>GMC10CG101J50NTLF</td>
</tr>
<tr>
<td>4</td>
<td>C23, C24, C25, C74</td>
<td>Capacitor, ceramic, 1 µF, 16V, 20%, Y5V, surface mount, 0603</td>
<td>TDK Corporation</td>
<td>C1608Y5V1C105Z</td>
</tr>
<tr>
<td>1</td>
<td>C26</td>
<td>Capacitor, Ceramic, 1 µF, 50V, 10%, X7R, surface mount, 0603</td>
<td>Taiyo Yuden Co., Ltd.</td>
<td>UMK107AB7105KA-T</td>
</tr>
</tbody>
</table>

**Note:** The components listed in this Bill of Materials are representative of the PCB assembly. The released BOM used in manufacturing uses all RoHS-compliant components.
### TABLE B-1: BILL OF MATERIALS (BOM) (CONTINUED)

<table>
<thead>
<tr>
<th>Qty.</th>
<th>Reference</th>
<th>Description</th>
<th>Manufacturer</th>
<th>Manufacturer Part Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>C31</td>
<td>Capacitor, ceramic, 4.7 µF, 50V, 10%, X7R, surface mount, 1206</td>
<td>TDK Corporation</td>
<td>C3216X7R1H475K160AC</td>
</tr>
<tr>
<td>1</td>
<td>D1</td>
<td>Diode, LED, green, 2.05V, 10 mA, clear, surface mount, 0603</td>
<td>Panasonic® - ECG</td>
<td>LNJ326W83RA</td>
</tr>
<tr>
<td>4</td>
<td>D3, D15, D26, D31</td>
<td>Diode, Schottky, 60V, 2A, surface mount, SOD-128, AEC-Q101</td>
<td>ROHM Semiconductor</td>
<td>RBR2LAM60BTFTTR</td>
</tr>
<tr>
<td>14</td>
<td>D4, D5, D7, D8, D9, D10, D11, D12, D13, D14, D27, D28, D29, D30</td>
<td>Diode, LED, red, 2.32V, 350 mA, 621 nm, clear, surface mount, 1108</td>
<td>OSRAM Opto Semiconductors GmbH.</td>
<td>KRDM-LQ31.23-HKYX-6-J3T3-Z</td>
</tr>
<tr>
<td>1</td>
<td>D6</td>
<td>Diode, LED, blue, 2.8V, 20 mA, 15 mcd, clear, surface mount, 0603</td>
<td>Lite-On®, Inc.</td>
<td>LTST-C193TBKT-5A</td>
</tr>
<tr>
<td>10</td>
<td>D16, D17, D18, D19, D20, D21, D22, D23, D24, D25</td>
<td>Diode, LED, yellow, 2.37V, 350 mA, 590 nm, clear, surface mount, 1108</td>
<td>OSRAM Opto Semiconductors GmbH.</td>
<td>KYDM-LQ31.23-HYXK-4-J3T3-Z</td>
</tr>
<tr>
<td>1</td>
<td>J1</td>
<td>Connector, HDR-2.54, male, 1x6, gold, 5.84MH, through hole, right angle</td>
<td>Amphenol Commercial</td>
<td>68016-106HLF</td>
</tr>
<tr>
<td>1</td>
<td>J2</td>
<td>Connector, power, 2 mm × 5.5 mm, switch, through hole, right angle</td>
<td>CUI Inc.</td>
<td>PJ-002A</td>
</tr>
<tr>
<td>1</td>
<td>J3</td>
<td>Connector, HDR-2.54, male, 1x6, tin, 5.84 MH, through hole, vertical</td>
<td>Sullins Connector Solutions</td>
<td>PEC06SAAN</td>
</tr>
<tr>
<td>4</td>
<td>J5, J6, J7, J8</td>
<td>Connector, HDR-2.54, male, 1x2, gold, 5.84 MH, through hole, vertical</td>
<td>Amphenol Commercial</td>
<td>77311-118-02LF</td>
</tr>
<tr>
<td>4</td>
<td>L1, L2, L3, L4</td>
<td>Inductor, 10 µH, 2.45A, 20%, surface mount, L12.3W12.3H6</td>
<td>Coilcraft</td>
<td>MSD1260-103MLB</td>
</tr>
<tr>
<td>4</td>
<td>LD1, LD2, LD3, LD4</td>
<td>Diode, LED, white, 2.95V, 350 mA, 70 lm, clear, surface mount, 1108</td>
<td>OSRAM Opto Semiconductors GmbH.</td>
<td>KW DMLQ33.SG-Z8KF7-EBVF FCB46-EE8G</td>
</tr>
<tr>
<td>1</td>
<td>PCB1</td>
<td>Printed Circuit Board - MCP1633 Automotive Tail Light Reference Design</td>
<td>Microchip Technology Inc.</td>
<td>04-01038</td>
</tr>
<tr>
<td>4</td>
<td>Q1, Q10, Q12, Q14</td>
<td>Transistor, FET, N-Channel, 60V, 6A, 1.7W, SOIC-8</td>
<td>Vishay Siliconix</td>
<td>SI4850EYT1-E3</td>
</tr>
<tr>
<td>4</td>
<td>Q2, Q9, Q11, Q13</td>
<td>Transistor, FET, N-Channel, 40V, 26A, 20W, WDFN-8</td>
<td>ON Semiconductor®</td>
<td>NVTS5C478NLWFTAG</td>
</tr>
<tr>
<td>5</td>
<td>Q4, Q5, Q6, Q7, Q8</td>
<td>Transistor, FET, N-Channel, 40V, 3A, 750 mW, SOT-23-3</td>
<td>Vishay Siliconix</td>
<td>SI2318DS-T1-GE3</td>
</tr>
<tr>
<td>2</td>
<td>Q15, Q16</td>
<td>Transistor, FET, N-Channel, 60V, 300 mA, 830 mW, SOT-23-3</td>
<td>NXP Semiconductors</td>
<td>2N7002,215</td>
</tr>
</tbody>
</table>

**Note:** The components listed in this Bill of Materials are representative of the PCB assembly. The released BOM used in manufacturing uses all RoHS-compliant components.
### TABLE B-1: BILL OF MATERIALS (BOM) (CONTINUED)

<table>
<thead>
<tr>
<th>Qty.</th>
<th>Reference</th>
<th>Description</th>
<th>Manufacturer</th>
<th>Manufacturer Part Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>R1</td>
<td>Resistor, thick film, 24 kΩ, 1%, 1/10W, surface mount, 0603</td>
<td>Panasonic - ECG</td>
<td>ERJ-3EKF2402V</td>
</tr>
<tr>
<td>1</td>
<td>R2</td>
<td>Resistor, thick film, 4.7 kΩ, 1%, 1/16W, surface mount, 0603</td>
<td>Multicomp Inc.</td>
<td>MC0063W060314K7</td>
</tr>
<tr>
<td>2</td>
<td>R3, R10</td>
<td>Resistor, thick film, 12 kΩ, 1%, 1/10W, surface mount, 0603</td>
<td>Yageo Corporation</td>
<td>RC0603FR-0712KL</td>
</tr>
<tr>
<td>3</td>
<td>R4, R25, R26</td>
<td>Resistor, thick film, 4.7 kΩ, 5%, 1/16W, surface mount, 0603</td>
<td>Panasonic - ECG</td>
<td>ERJ-3GEYJ472V</td>
</tr>
<tr>
<td>13</td>
<td>R5, R6, R11, R28, R32, R39, R48, R52, R59, R67, R71, R78, R86</td>
<td>Resistor, thin film, 100 kΩ, 1%, 1/8W, surface mount, 0603</td>
<td>Vishay Beyschlag</td>
<td>MCT06030C1003FP500</td>
</tr>
<tr>
<td>4</td>
<td>R7, R29, R49, R68</td>
<td>Resistor, thick film, 4.7R, 1%, 1/10W, surface mount, 0603</td>
<td>Panasonic - ECG</td>
<td>ERJ-3RQF4R7V</td>
</tr>
<tr>
<td>1</td>
<td>R8</td>
<td>Resistor, thick film, 210 kΩ, 1%, 1/10W, surface mount, 0603</td>
<td>Panasonic - ECG</td>
<td>ERJ-3EKF2103V</td>
</tr>
<tr>
<td>20</td>
<td>R9, R15, R16, R21, R22, R31, R36, R37, R42, R43, R51, R56, R57, R62, R63, R70, R75, R76, R81, R82</td>
<td>Resistor, thick film, 1 kΩ, 1%, 1/10W, surface mount, 0603</td>
<td>Panasonic - ECG</td>
<td>ERJ3EKF1001V</td>
</tr>
<tr>
<td>4</td>
<td>R12, R33, R53, R72</td>
<td>Resistor, thick film, 0.1R, 1%, 1/10W, surface mount, 0603</td>
<td>Panasonic - ECG</td>
<td>ERJ-8BWFR100V</td>
</tr>
<tr>
<td>4</td>
<td>R13, R34, R54, R73</td>
<td>Resistor, thick film, 51 kΩ, 1%, 1/10W, surface mount, 0603</td>
<td>Panasonic - ECG</td>
<td>ERJ-3EKF5102V</td>
</tr>
<tr>
<td>8</td>
<td>R14, R35, R55, R74, R87, R88, R89, R90</td>
<td>Resistor, thick film, 10 kΩ, 1%, 1/16W, surface mount, 0603</td>
<td>TE Connectivity, Ltd.</td>
<td>CPF0603F10KC1</td>
</tr>
<tr>
<td>2</td>
<td>R17, R41</td>
<td>Resistor, thick film, 0.22R, 1%, 1/2W, surface mount, 1206</td>
<td>Vishay/Dale</td>
<td>RCWE1206R220FKEA</td>
</tr>
<tr>
<td>4</td>
<td>R19, R40, R60, R79</td>
<td>Resistor, thick film, 4.02 kΩ, 1%, 1/10W, surface mount, 0603</td>
<td>Stackpole Electronics, Inc.</td>
<td>RMCF0603FT4K02</td>
</tr>
<tr>
<td>3</td>
<td>R20, R61, R80</td>
<td>Resistor, thick film, 220R, 1%, 1/10W, surface mount, 0603</td>
<td>Yageo Corporation</td>
<td>RC0603FR-07220RL</td>
</tr>
<tr>
<td>8</td>
<td>R23, R24, R44, R64, R65, R83, R84</td>
<td>Resistor, thick film, 20 kΩ, 1%, 1/10W, surface mount, 0603</td>
<td>Panasonic - ECG</td>
<td>ERJ3EKF2002V</td>
</tr>
<tr>
<td>4</td>
<td>R27, R66, R77, R85</td>
<td>Resistor, thick film, 10R, 1%, 1/10W, surface mount, 0603</td>
<td>Panasonic - ECG</td>
<td>ERJ-3EKF10R0V</td>
</tr>
<tr>
<td>1</td>
<td>R30</td>
<td>Resistor, thick film, 220 kΩ, 1%, 1/10W, surface mount, 0603</td>
<td>Panasonic - ECG</td>
<td>ERJ-3EKF2203V</td>
</tr>
<tr>
<td>2</td>
<td>R38, R58</td>
<td>Resistor, thick film, 0.680R, 1%, 1/4W, surface mount, 1206</td>
<td>TE Connectivity, Ltd.</td>
<td>1-1622824-3</td>
</tr>
</tbody>
</table>

**Note:** The components listed in this Bill of Materials are representative of the PCB assembly. The released BOM used in manufacturing uses all RoHS-compliant components.
TABLE B-1: BILL OF MATERIALS (BOM) (CONTINUED)

<table>
<thead>
<tr>
<th>Qty.</th>
<th>Reference</th>
<th>Description</th>
<th>Manufacturer</th>
<th>Manufacturer Part Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>R45</td>
<td>Resistor, thick film, 10 kΩ, 5%, 1/2W, surface mount, 0805</td>
<td>Panasonic - ECG</td>
<td>ERJ-P06J103V</td>
</tr>
<tr>
<td>1</td>
<td>R47</td>
<td>Resistor, thick film, 2.7 kΩ, 1%, 1/10W, surface mount, 0603</td>
<td>Panasonic - ECG</td>
<td>ERJ-3EKF2701V</td>
</tr>
<tr>
<td>1</td>
<td>R50</td>
<td>Resistor, thick film, 105 kΩ, 1%, 1/16W, surface mount, 0603</td>
<td>Panasonic - ECG</td>
<td>ERJ-3EKF1053V</td>
</tr>
<tr>
<td>1</td>
<td>R69</td>
<td>Resistor, thick film, 127 kΩ, 1%, 1/10W, surface mount, 0603</td>
<td>Panasonic - ECG</td>
<td>ERJ-3EKF1273V</td>
</tr>
<tr>
<td>2</td>
<td>SW1, SW2</td>
<td>Switch, tactile, SPST, 24V, 50 mA, surface mount</td>
<td>TE Connectivity</td>
<td>147873-1</td>
</tr>
<tr>
<td>13</td>
<td>TP2, TP3, TP6, TP12, TP13, TP16, TP19, TP20, TP21, TP24, TP28, TP30, TP33</td>
<td>Misc., test point multi-purpose mini black</td>
<td>Keystone® Electronics Corp.</td>
<td>5001</td>
</tr>
<tr>
<td>1</td>
<td>U1</td>
<td>Microchip Analog LDO, 5V MCP1790, SOT-223-3</td>
<td>Microchip Technology Inc.</td>
<td>MCP1790T-5002E/DB</td>
</tr>
<tr>
<td>1</td>
<td>U2</td>
<td>Microchip MCU 8-BIT, 32 MHz, 14K, 1K, PIC16F15355, 6 mm × 6 mm UQFN-28</td>
<td>Microchip Technology Inc.</td>
<td>PIC16F15355-E/MX</td>
</tr>
<tr>
<td>4</td>
<td>U3, U8, U10, U12</td>
<td>Microchip Analog PWM Controller, 2.2 MHz, MCP1633, QFN-16</td>
<td>Microchip Technology Inc.</td>
<td>MCP1633-E/MG</td>
</tr>
<tr>
<td>1</td>
<td>U4</td>
<td>Microchip RF Bluetooth, RN4871, Module-16</td>
<td>Microchip Technology Inc.</td>
<td>RN4871-V/RM118</td>
</tr>
<tr>
<td>1</td>
<td>U5</td>
<td>Microchip Analog voltage detector, 1.9V, MCP112, SOT-23-3</td>
<td>Microchip Technology Inc.</td>
<td>MCP112T-195I/TT</td>
</tr>
<tr>
<td>4</td>
<td>U6, U9, U11, U13</td>
<td>Microchip Analog temperature sensor, -40°C to +150°C, MCP9700, SOT-23-3</td>
<td>Microchip Technology Inc.</td>
<td>MCP9700AT-E/TT</td>
</tr>
<tr>
<td>1</td>
<td>U7</td>
<td>Microchip Analog LDO, 3.3V, MCP1703, SOT-23A-3</td>
<td>Microchip Technology Inc.</td>
<td>MCP1703AT-3302E/DB</td>
</tr>
</tbody>
</table>

Note: The components listed in this Bill of Materials are representative of the PCB assembly. The released BOM used in manufacturing uses all RoHS-compliant components.

TABLE B-2: BILL OF MATERIALS (BOM) - MECHANICAL PARTS

<table>
<thead>
<tr>
<th>Qty.</th>
<th>Reference</th>
<th>Description</th>
<th>Manufacturer</th>
<th>Manufacturer Part Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>PAD1, PAD2, PAD3, PAD4</td>
<td>Mechanical H.W. rubber pad, cylindrical, D7.9, H5.3, black</td>
<td>3M</td>
<td>70006431483</td>
</tr>
</tbody>
</table>

Note: The components listed in this Bill of Materials are representative of the PCB assembly. The released BOM used in manufacturing uses all RoHS-compliant components.
Appendix C. Typical Performance Data, Curves and Waveforms

C.1 INTRODUCTION

This chapter shows some of the typical performance parameters and curves of the MCP1633 Automotive Tail Light Reference Design.

C.2 BRAKE I\textsubscript{OUT} DIMMING

C.3 BRAKE I\textsubscript{OUT} RIPPLE
C.4  FOG - MINIMUM LEVEL OF DIMMING

C.5  FOG $I_{OUT}$ RIPPLE
C.6  POSITION $I_{\text{OUT}}$ RIPPLE

C.7  TURN $I_{\text{OUT}}$ RIPPLE
C.8 TURN $V_{OUT}$ AND $I_{OUT}$

![Graph showing $V_{OUT}$ and $I_{OUT}$](image1)

C.9 TURN ALL STEPS PERIOD OF TIME

![Graph showing $V_{OUT}$ and $I_{OUT}$](image2)
## Worldwide Sales and Service

### AMERICAS

**Corporate Office**  
2355 West Chandler Blvd.  
Chandler, AZ 85224-6199  
Tel: 480-792-7200  
Fax: 480-792-7277  
Technical Support: http://www.microchip.com/support  
Web Address: www.microchip.com

- **Atlanta**  
  Duluth, GA  
  Tel: 678-957-9614  
  Fax: 678-957-1455

- **Austin, TX**  
  Tel: 512-257-3370

- **Boston**  
  Westborough, MA  
  Tel: 508-858-3550  
  Fax: 508-858-3555

- **Chicago**  
  Itasca, IL  
  Tel: 630-285-0071  
  Fax: 630-285-0075

- **Dallas**  
  Addison, TX  
  Tel: 972-818-7423  
  Fax: 972-818-2924

- **Detroit**  
  Novi, MI  
  Tel: 248-848-4000

- **Houston, TX**  
  Tel: 281-894-5983

- **Indianapolis**  
  Noblesville, IN  
  Tel: 317-773-8323  
  Fax: 317-773-5453  
  Tel: 317-536-2380

- **Los Angeles**  
  Mission Viejo, CA  
  Tel: 949-462-9523  
  Fax: 949-462-9608  
  Tel: 951-273-7800

- **Raleigh, NC**  
  Tel: 919-844-7510

- **New York, NY**  
  Tel: 631-435-6000

- **San Jose, CA**  
  Tel: 408-735-9110  
  Tel: 408-436-4270

- **Canada - Toronto**  
  Tel: 905-695-1980  
  Fax: 905-695-2078

### ASIA/PACIFIC

- **Australia - Sydney**  
  Tel: 61-2-9888-6733

- **China - Beijing**  
  Tel: 86-10-8569-7000

- **China - Chengdu**  
  Tel: 86-28-8665-5511

- **China - Chongqing**  
  Tel: 86-23-8980-9588

- **China - Dongguan**  
  Tel: 86-769-8702-9880

- **China - Guangzhou**  
  Tel: 86-20-8755-8029

- **China - Hangzhou**  
  Tel: 86-571-8792-8115

- **China - Hong Kong SAR**  
  Tel: 852-2943-5100

- **China - Nanjing**  
  Tel: 86-25-8755-3260

- **China - Qingdao**  
  Tel: 86-532-8502-7355

- **China - Shanghai**  
  Tel: 86-21-3326-8000

- **China - Shenyang**  
  Tel: 86-24-2334-2829

- **China - Shenzhen**  
  Tel: 86-755-8864-2200

- **China - Suzhou**  
  Tel: 86-186-6233-1526

- **China - Wuhan**  
  Tel: 86-27-5980-5300

- **China - Xiamen**  
  Tel: 86-3-8833-7252

- **China - Zhuhai**  
  Tel: 86-756-3210040

### ASIA/PACIFIC

- **India - Bangalore**  
  Tel: 91-80-3090-4444

- **India - New Delhi**  
  Tel: 91-11-4160-8631

- **India - Pune**  
  Tel: 91-20-4121-0141

- **Japan - Osaka**  
  Tel: 81-6-6152-7160

- **Japan - Tokyo**  
  Tel: 81-3-6880-3770

- **Korea - Daegu**  
  Tel: 82-53-744-4301

- **Korea - Seoul**  
  Tel: 82-2-554-7200

- **Malaysia - Kuala Lumpur**  
  Tel: 60-3-7651-7906

- **Malaysia - Penang**  
  Tel: 60-4-277-8870

- **Philippines - Manila**  
  Tel: 63-2-634-9065

- **Singapore**  
  Tel: 65-6334-8870

- **Taiwan - Hsin Chu**  
  Tel: 886-3-577-8366

- **Taiwan - Kaohsiung**  
  Tel: 886-7-213-7830

- **Taiwan - Taipei**  
  Tel: 886-2-2508-8600

- **Thailand - Bangkok**  
  Tel: 66-2-694-1351

- **Vietnam - Ho Chi Minh**  
  Tel: 84-28-5446-2100

### EUROPE

- **Austria - Wels**  
  Tel: 43-7242-2244-39  
  Fax: 43-7242-2244-393

- **Denmark - Copenhagen**  
  Tel: 45-4485-5910  
  Fax: 45-4485-2829

- **Finland - Espoo**  
  Tel: 358-9-4520-820

- **France - Paris**  
  Tel: 33-1-69-53-63-20  
  Fax: 33-1-69-30-90-79

- **Germany - Garching**  
  Tel: 49-8931-9700

- **Germany - Haan**  
  Tel: 49-2129-3766400

- **Germany - Heilbronn**  
  Tel: 49-7131-72400

- **Germany - Karlsruhe**  
  Tel: 49-721-625370

- **Germany - Munich**  
  Tel: 49-89-627-144-0  
  Fax: 49-89-627-144-44

- **Germany - Rosenheim**  
  Tel: 49-8031-354-560

- **Israel - Ra'anana**  
  Tel: 972-9-744-7705

- **Italy - Milan**  
  Tel: 39-0331-742611  
  Fax: 39-0331-466781

- **Italy - Padova**  
  Tel: 39-049-7625286

- **Netherlands - Drunen**  
  Tel: 31-416-690399  
  Fax: 31-416-690340

- **Norway - Trondheim**  
  Tel: 47-7288-4388

- **Poland - Warsaw**  
  Tel: 48-22-3325737

- **Romania - Bucharest**  
  Tel: 40-21-407-87-50

- **Spain - Madrid**  
  Tel: 34-91-708-08-90  
  Fax: 34-91-708-08-91

- **Sweden - Gothenberg**  
  Tel: 46-31-704-60-40

- **Sweden - Stockholm**  
  Tel: 46-8-5090-4654

- **UK - Wokingham**  
  Tel: 44-118-921-5800  
  Fax: 44-118-921-5820

---

DS50002920A-page 41 © 2020 Microchip Technology Inc. 02/28/20